AN4004

±2g Acceleration Sensing Module Based on a ±40g Integrated Accelerometer

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INTRODUCTION

Micromachined accelerometers, with built–in signal conditioning and calibration are widely used in automotive safety devices such as airbag modules. Automotive applications for accelerometers also include comfort features such as active suspension. For such an application, a ±2g accelerometer is required. But most accelerometers offered today that are able to provide sufficient sensitivity are expensive and/or unavailable in production volumes. With the circuitry described herein, the accelerometer can be used for sensing acceleration in the range of ±2g, with performance in line with the technical requirements of this application.

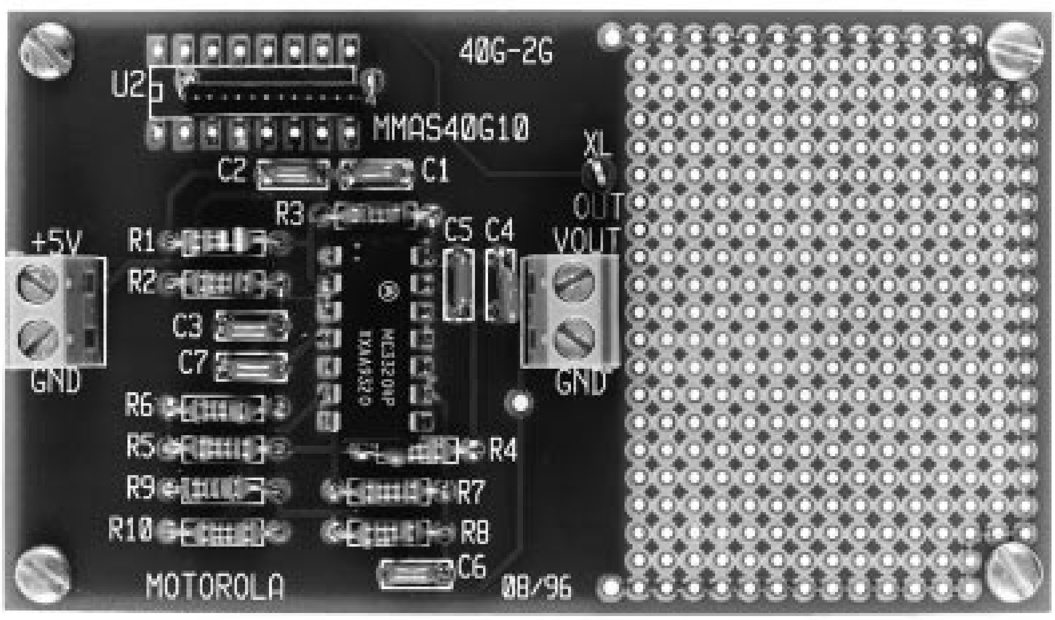

Figure 1. 40G–2G ±2g Sensing Module Evaluation Board

EVALUATION BOARD DESCRIPTION

The information required to use evaluation board "40G–2G" follows and a discussion of the design appears in the Design Considerations section.

Function

The evaluation board shown in Figure 1, when supplied with an accelerometer, provides a ±2g full scale acceleration measurement.

The output is an analog signal. It nominally supplies 2.1 volts at zero g and has a sensitivity of 1000 mV/g. It is easily interfaced with a microcontroller's A/D input.

A through–hole area is provided on the PCB for the designer to add other circuitry as needed.

Electrical Characteristics

The following electrical characteristics are included as a guide to operation.

Characteristics	Symbol	Min	Typ	Max	Units
Supply Voltage	V_{CC}	4.75	5.0	5.25	Volts
Supply Current	I_O	—	7.0	—	mA
Acceleration Range	G	–2.0	—	+2.0	g
Zero G Output	V_{off}	2.0	2.1	2.2	Volts
Sensitivity	$\Delta V/\Delta G$	850	1000	1150	mV/g
Low Cutoff Frequency	—	0.8	0.9	1.0	Hz
High Cutoff Frequency	—	4.0	5.0	6.0	Hz
Operating Temperature	Ta	–40	—	+85	°C

Table 1. Electrical Characteristics

Frequency Response

Below is the simulated typical output frequency response using the devices listed in the parts list below. The system provides a gain of 25 over a 5 Hz bandwidth.

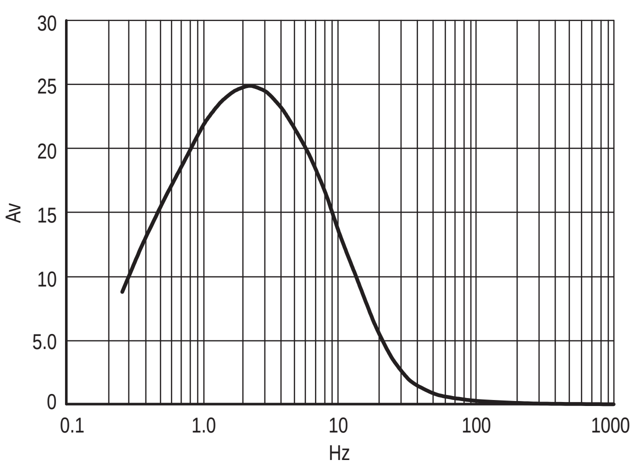

Figure 2. ±2g Biquad Filter with Additional Gain Stage Frequency Response

Evaluation Board Content

Board contents are described in the parts list shown in Table 2. A schematic and silk screen plot are shown in Figures 4 and 5.

Designator	Qty.	Description	Value/Part Number
R1	1	1/4 Watt Resistor	90.9 K
R2, R8	2	1/4 Watt Resistor	162 K
R5, R6, R7, R9, R10	5	1/4 Watt Resistor	11 K
R3, R4	2	1/4 Watt Resistor	432 K
C1–C6	6	Ceramic Capacitor	0.1 µF
U1	1	Quad Rail–to–Rail Op Amp	MC33204P
U2	1	40g Accelerometer	MMA2200W

Table 2. Parts List

DESIGN CONSIDERATIONS

Using a 40g accelerometer to measure ±2g of acceleration can be tricky. Motorola's accelerometer provides a wide bandwidth of 400 Hz for acceleration sensing. In many low g applications, such as active suspension, the bandwidth requirements are considerably lower. Limiting the bandwidth of the accelerometer can reduce noise. After reducing the bandwidth, gain can be applied to provide higher sensitivity for low g acceleration measurements.

The design challenge is how to bandpass filter the accelerometer's output with gain using a few low cost components. To accommodate the accelerometer's wide dynamic range, since the supply voltage is limited to 5 volts, it is necessary to use rail to rail operational amplifiers, such as Motorola's MC33204P.

In this design, the output signal passes through a biquad filter stage, then through an additional low–pass gain stage to provide ±2g sensing capability. The biquad filter, shown in Figure 3, with some gain, is a good choice for bandpass filtering the accelerometer output when a high quotient factor, Q, is desired. The gain is set by Rg and Rb with the high cutoff frequency being set by Rb and C1. The low cutoff frequency is set by Rf and C2.

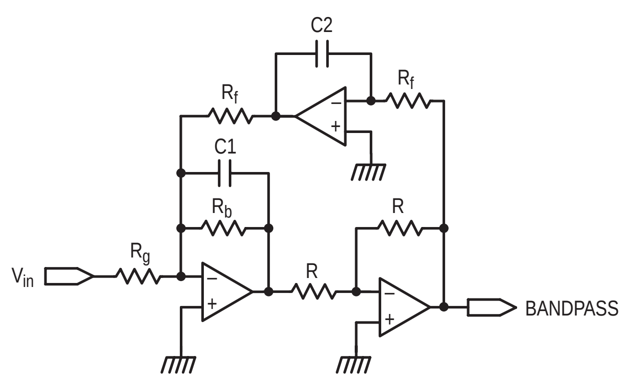

Figure 3. Biquad Active Filter

APPLICATION

Integrating the accelerometer with the biquad amplifier is quite simple. First, in order to minimize the noise level, the accelerometer is properly bypassed, as indicated in the data sheet, with one 0.1 μF ceramic capacitor between V_{CC} (pin 8) and Ground (pin 7). The self–test feature remains unused in this design. Pin 11 is tied to V_{CC}, as indicated in the data sheet. The output signal is taken on pin 5. The remaining pins of the accelerometer are unused.

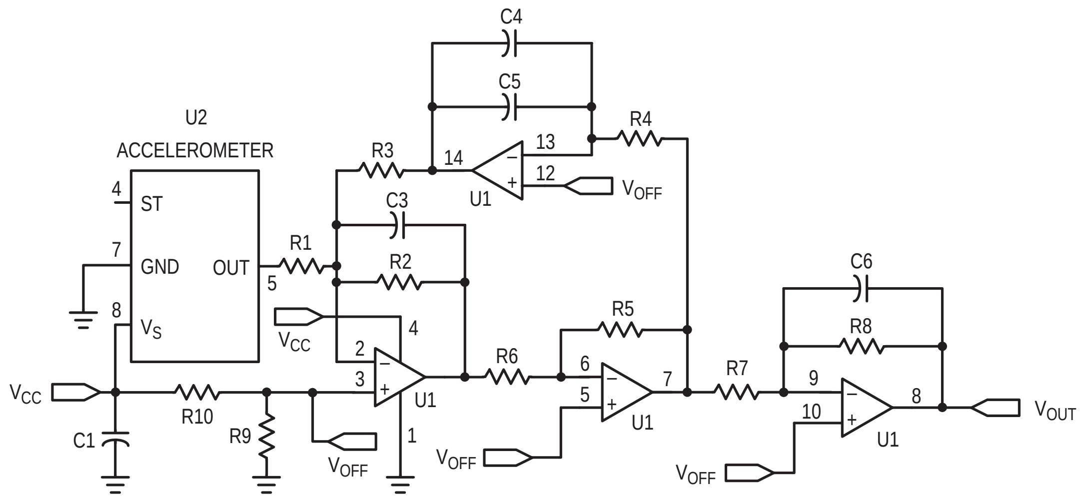

Figure 4. ±2g Acceleration Sensing Module EVB Schematic

In this design, the biquad filter stage gain is set to 1.76 with R2 (160 kΩ) and R1 (91 kΩ). A higher gain cannot be set for this stage, otherwise some operational amplifiers saturate when the accelerometer output drifts over temperature. The upper cutoff frequency is set with R2 (160 kΩ) and C3 (0.1 μF). Two capacitors, C4 (0.1 μF) and C5 (0.1 μF), are needed to set the lower cutoff frequency.

A final low pass filter stage, with a gain of 14.55, brings the overall gain to 25. Resistors R8 (160 kΩ) and R7 (11 kΩ) set the gain. The amplifier is low passed with C6 (0.1 μF) to remove any high frequency noise in the signal. The output can then be connected to a microcontroller's A/D converter by a simple direct connection from the evaluation board analog output V_{OUT} to the A/D input. Using the MC68HC11 as an example, the output is connected to any of the E ports.

Since the accelerometer signal passes through 3 inverter stages, the positive direction of acceleration is reversed.

CONCLUSION

Perhaps the most noteworthy aspect to the ±2g sensing module described here is the ease with which it can be designed. Only two dual, or one quad, operational amplifier and a few resistors and capacitors are required. The result is a simple and inexpensive circuit that is capable to measure acceleration within the range of ±2g with an analog output that can be directly interfaced to a microcontroller.

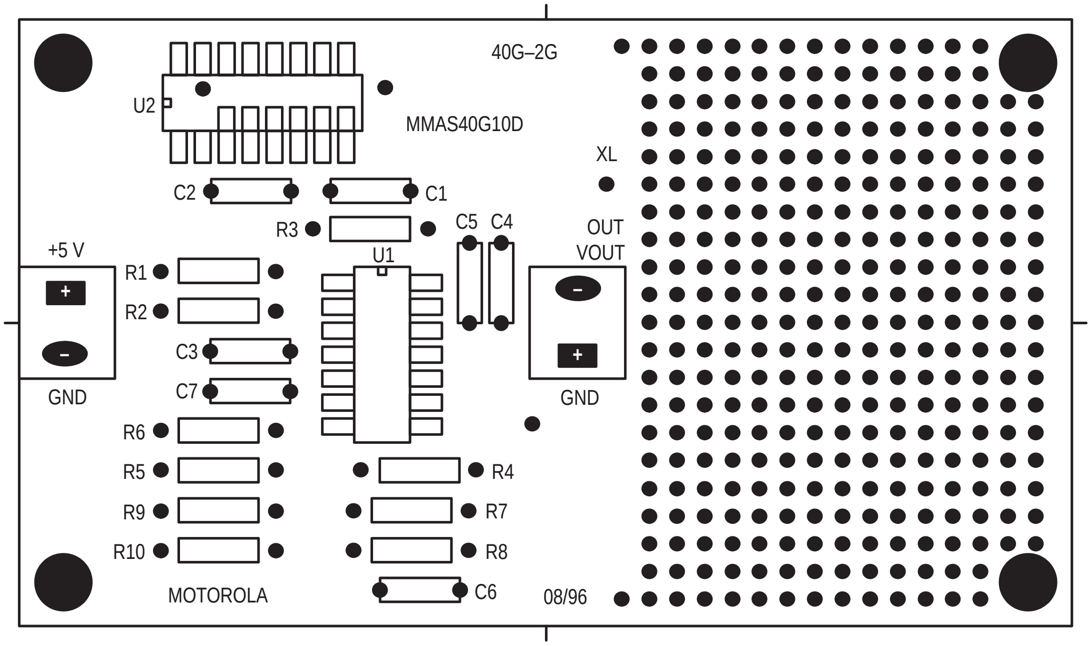

Figure 5. Silk Screen

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